

Pre-College Education Programs at CEBAF

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Abstract

As a DOE nuclear physics basic research laboratory, the Continuous Electron Beam Accelerator Facility (CEBAF) provides a rich environment for precollege science education. Several innovative partnerships with schools, businesses, and academia demonstrate model approaches for enhancing teachers and motivating students. Becoming Enthusiastic About Math and Science (BEAMS) immerses classes of 5th/6th graders for a full week at CEBAF. Our FCCSET Summer Institute equips teachers to "do science" in their middle and high school classes.

Introduction

The Continuous Electron Beam Accelerator Facility (CEBAF) is a \$600-million basic research laboratory funded by the U.S. Department of Energy and being built in Newport News, Virginia, to study and understand the detailed structure and behavior of the nucleus of the atom. Physics experiments are scheduled to start in 1994. In the summer of 1993 construction of the accelerator facility and research equipment is 90% complete. Work underway includes planning experiments, building detectors, and commissioning the accelerator. Low-temperature cryogenics, superconductivity, clean room assembly, and computer control and modeling are part of daily activities at the laboratory. With the forefront technologies and experiments being conducted by expert scientific and technical staff, CEBAF is a significant resource for science and math education.

CEBAF's mission in precollege education is to pioneer creative, innovative, and effective educational partnerships that capitalize on the strengths and assets of CEBAF to address national education needs and priorities, and serve as models for the federal-laboratory, business, and education communities. These pre-college science and math education programs are intertwined with CEBAF's scientific and technical activities, safely engaging participants with the full spectrum of personnel, facilities, technologies, and activities involved in advancing the frontiers of knowledge. An important goal is to pilot promising, sustainable programs, and to work together with other laboratories, school districts, and businesses to replicate the programs in other communities. This paper describes some of the efforts in pre-college education underway at CEBAF.

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CEBAF'S Pre-college Education Program

Overview

Since 1985, CEBAF's education efforts have evolved from *ad hoc*, small-scale outreach activities to formalized educational programs conducted in partnership with local, regional, and state education authorities. Participation in CEBAF's K-12 programs averages about 10,000 students and 1,500 teachers each year.

CEBAF's goals for pre-college math and science education are to:

- o Support, enhance, and empower teachers
- o Motivate students, especially those traditionally underrepresented in science
- o Involve parents
- o Enlist other organizations to support pre-college education similarly
- o Thoroughly evaluate the effectiveness and impact of education programs

Teacher Enhancement Programs

CEBAF's teacher enhancement programs respond to the highest priority national needs, by providing information, awareness, or R&D experiences to some 1,500 teachers annually. About 100 of these teachers interact extensively with CEBAF via one of three programs: eight-week summer research fellowships, a four-week summer teacher institute, and hands-on activity training plus a week on-site with students for BEAMS (Becoming Enthusiastic About Math and Science). The remainder attend short in-service programs, tours, or science lectures. The majority of participating teachers work in local or regional school districts, where CEBAF is an accessible neighbor and resource. In addition, selected teachers drawn from a national pool participate in the intensive programs to become familiar with CEBAF's science, technology, and educational activities for the benefit of populations far from our site.

Summer research fellowships

CEBAF hosts summer research fellowships for middle and high school teachers, administered through the DOE-sponsored Teacher Research Associates (TRAC) Program. These eight-week fellowships allow teachers to work with mentors at CEBAF on projects at the forefront of science and technology. Each teacher spends 75% of his/her time on a research project with a CEBAF mentor and 25% on development of classroom applications. Additionally, a seminar series is given which provides an introduction to a broad range of CEBAF-related topics. Graduate credit is available to the teacher fellows through a local university.

Summer teacher institute

The Summer Institute for Teacher Enhancement at CEBAF (CEBAF-SITE) is a teacher enhancement institute responsive to the priorities of the Federal Coordinating Council on Science, Engineering, and Technology (FCCSET). This institute is connected with and serves the goals and objectives of statewide systemic reform initiatives of Virginia and nearby states. The specific goal of CEBAF-SITE is to develop the teachers' ability to teach science by actually doing science in their classrooms.

Offered for the first time in Summer 1993, CEBAF-SITE targets physics, physical science, and engineering/technology teachers. Participants included 24 middle school teachers and 24 high school teachers from Louisiana, North Carolina, Pennsylvania, Texas, Virginia, and West Virginia. Their teaching assignments ranged from 6th grade science through general and A.P. physics, and included engineering science and 8th grade physical science. A special highlight capitalized on the unique opportunity for the teachers to interact with

students and teachers involved in the International Physics Olympiad held nearby at the College of William and Mary (the first time this prestigious competition was hosted by the United States). Over half of the teachers paid to enroll for four graduate credit hours in physics from a local university.

The CEBAF-SITE combined 65 hours of group research projects at CEBAF with 95 hours of classroom instruction, field trips, and workshops on physics, physical science, technology, effective pedagogy, and computer networking. Figure 1 shows the schedule of workshops and field trips, which were held in the mornings. In the afternoons the teachers worked in teams of four or five with a CEBAF staff mentor on a real research project. These projects were selected to be doable in the short time available, to be genuinely useful to CEBAF, and to require the teachers to develop a viable research approach and methodology. Examples included studying and mapping magnetic fields in a test area, studying accelerator vacuum components for their helium absorption, and observing accelerator materials using a scanning electron microscope.

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
<p>♦ indicates an evening session</p> <p>▲ workshop sessions alternate with 2 groups</p>	<p>CEBAF program orientation, facility tour, and mentor planning sessions</p> <p>Dianne Robinson - "Ice Breaker" (at CEBAF) 6/28</p>	<p>Ron Giese - "Experimental Design & Analysis" (at CEBAF)</p> <p>♦ Ron Vasaturo - "SURAnet" group 1 6/29</p>	<p>Ron Giese - "Exper. Design & Analysis" (at CEBAF)</p> <p>♦ Ron Vasaturo - "SURAnet" group 2 6/30</p>	<p>Ron Giese - "Exper. Design & Analysis" (at CEBAF) 7/1</p>	<p>Arlene Macin - "Optical Physics" (at HU) ▲</p> <p>Warren Buck - "Hadrons" (at HU) ▲ 7/2</p>	
	<p>July 5 - Holiday (CEBAF closed) 7/5</p>	<p>David Wright - Busch Gardens visit (9:00-4:00) (in Williamsburg) (CEBAF closed) 7/6</p>	<p>Randy Caton - "Design Challenges" part 1 (at CNU) 7/7</p>	<p>Randy Caton - "Design Challenges" (at CNU) part 2</p> <p>Dr. Jane Sutsman - NSF overview 2:00 - 3:30 pm (at CEBAF) 7/8</p>	<p>Randy Caton - "Design Challenges" part 3</p> <p>Anita Feldman - "Gender Equity Issues in M & S" (at CEBAF) 7/9</p>	<p>Science Museum of Virginia - Physics Workshop, tour, film & lunch (8:00-4:00) (in Richmond) 7/10</p>
<p>Opening Ceremonies for "24th International Olympiad" 11:00 am (at W&M) 7/11</p>	<p>Jake Becher - "Scientific Reasoning" part 1 (at ODU-PC)</p> <p>Leon Lederman presentation - 1pm 7/12</p>	<p>Vince Childress - "Sci., Math & Tech. Integrative Workshop" (at CEBAF) 7/13</p>	<p>"24th International Physics Olympiad" teachers visit, tour CEBAF & lunch with SITE teachers 7/14</p>	<p>Dick Lindgren - "Electrostatics" (at CEBAF)</p> <p>♦ Olympiad Activity - at W&M 7/15</p>	<p>Bob Gordon - "Acceleration & Radioactive Decay" (at CEBAF) 7/16</p>	<p>Va. Air & Space Center tour & NASA TRC 8:30 - noon (in Hampton)</p> <p>Closing Ceremonies for 24th International Olympiad 2:00-5:00 (in W & M) 7/17</p>
	<p>Judy Shay - "In-service Strategies for Teachers" ▲</p> <p>Ron Giese - Exp. Design follow-up ▲ (at CEBAF)</p> <p>Concurrent Administrators Workshops 7/19</p>	<p>Dennis Mahos - "Electricity and Magnetism" (at CEBAF)</p> <p>♦ Va. Marine Science Museum (at VMSM)</p> <p>Administrators Workshops 7/20</p>	<p>NASA Educ. staff NASA Tour + visit to research sites (at NASA) 7/21</p>	<p>Jake Becher - "Scientific Reasoning" part 2</p> <p>Cheryl Evans - "Diversity & Multiculturalism" (at ODU-PC) 7/22</p>	<p>Final Day at CEBAF</p> <p>Teacher Presentations</p> <p>Graduation Ceremonies 7/23</p>	

CEBAF-SITE Workshop and Field Trip Schedule

Figure 1

Teachers developed experiments to take back to school, and committed to share what they learned with colleagues in their districts. To ensure that school and district administrators support the teachers' new skills and approaches, a two-day program for principals, superintendents, and science supervisors was held during the institute.

Numerous surveys were administered as part of a structured evaluation program. We used daily and weekly surveys to learn what was particularly effective and valuable, as well as to identify teachers' issues and concerns so they could be addressed promptly. Over 95% of the participants indicated that to a great extent they gained increased knowledge of classroom

applications and new perspectives on teaching. For the teachers, the research projects were the favorite and most rewarding component of the institute, as few of them had any prior research experience. Over 60% of the teachers rated CEBAF-SITE within the top 10% of teacher enhancement programs they had participated in, and an additional 25% rated it in the top quartile. The biggest complaint was that we crammed too many worthwhile activities into too short a time, and effectively wore out the teachers and ourselves. We plan follow-up in the form of a school-year workshop, phone contact, and computer networking. This post-institute interaction will support and encourage the teachers, and will allow them to learn from each other by sharing their problems and successes.

The institute was organized by a collaboration with representatives from CEBAF, Christopher Newport University, College of William and Mary, Hampton University, Old Dominion University, University of Virginia, Cooperating Hampton Roads Organizations for Minorities in Engineering (CHROME), Hampton City Schools, and Newport News Schools. The Virginia Space Grant Consortium assumed responsibility for organizing the workshops and field trips.

Teachers Becoming Enthusiastic About Math and Science (BEAMS) program

Becoming Enthusiastic About Math and Science (BEAMS) is a partnership with local school districts to give students meaningful, grade-appropriate scientific and technical experiences, thereby enhancing their motivation and achievement in school, and their awareness of diverse career options. As part of this program, classes with their teachers spend two days to a week on site at CEBAF, and teachers receive ideas and instructions for reinforcement activities to use in their classrooms before and after the on-site experience. Before their classroom visit, BEAMS teachers are given an intensive orientation to CEBAF and a book of motivational, hands-on, question-driven science and math activities.¹ The teachers are encouraged to integrate the CEBAF experience into their annual curriculum.

Since 1991, BEAMS has involved 100 5th and 6th grade classes and teachers. Beginning in school year 1993/94, we plan to initiate a phased expansion of BEAMS, which will ultimately include 4th through 10th grades, with the same students returning every year. The teacher component of BEAMS will evolve in parallel to serve the science and math teachers of all the BEAMS classes, and to provide orientation for the teachers of other subject areas.

Student-Oriented Programs

What characterizes many successful scientific and engineering personnel at CEBAF and other laboratories is their enthusiasm about the subject matter and their confidence about building, tackling, or discovering something new. When asked where this interest originated, most recall childhood experiences and encouragement that motivated them and made math and science real and attractive. Such experiences are rare in the U.S. today, except for children whose parents or other very close adult mentors happen to work in technical jobs.

Our student-oriented programs provide for many students the kinds of motivational experiences and encouragement that got us hooked on science, engineering, and math. These programs emphasize motivation, and seek to increase science/math interest, decrease science/math anxiety, and recognize the value of education. Of the 10,000 students currently exposed to CEBAF each year, about 1,100 are 5th or 6th graders having intensive, week-long interactions with the lab and its staff through the BEAMS program (Becoming Enthusiastic About Math and Science) described below. The remainder attend monthly evening science presentations on diverse topics called the CEBAF Science Series, have short tours, or participate in various outreach and career awareness activities.

¹ CEBAF, BEAMS Handbook, 1991 and 1992 Editions.

Becoming Enthusiastic About Math and Science (BEAMS)

BEAMS History. In 1991, CEBAF, in partnership with Newport News Public Schools and funded by the Department of Energy Office of Science Education and Technical Information, launched the BEAMS Program. Called BEAMS for "Becoming Enthusiastic About Math and Science," the program brings inner-city fifth and sixth grade classes with their teachers to CEBAF for a specially modified version of their regular academic week. BEAMS motivates students by exposing them to science's excitement, challenges, opportunities, and career options. For five consecutive days during school hours, the children and their teacher are immersed in CEBAF's forefront research environment, where they participate in science and math events and activities conducted with scientists, engineers, and technicians. These activities inform students about CEBAF's science, technologies, and career options. A major emphasis is to encourage students to ask questions, to make and test predictions, and to realize that there isn't always one correct answer. Each student is given a BEAMS log book² for record keeping and activity reinforcement. BEAMS takes place in a CEBAF on-site classroom, outdoors, in the staff cafeteria, and in laboratories, assembly areas, and at the accelerator site. In short, the class experiences CEBAF for the entire week. Since BEAMS' inception, 2,500 students (over 50% minority) and 100 teachers from four nearby school districts have participated. Available facilities at CEBAF permit only two classes to be on site simultaneously.

Each week about 20 different role-model volunteers drawn from our staff of physicists, engineers, designers, computer programmers, and technicians conduct the activities with the students. Each person spends a few minutes introducing himself or herself and describes how and why he or she got interested in and trained for the job he or she has at CEBAF. We have two to four staff volunteers plus the classroom teacher involved in each activity, making the ratio between students and knowledgeable adults range from 8:1 to 5:1. The schedule for a typical week is shown in Figure 2.

One staff member is assigned to be the "Class Mentor" and visits the class prior to and after its week at CEBAF. The mentor talks to the class about CEBAF and his/her job and background. Questions and orientation or follow-up discussions occur. The class mentor typically participates in one or more activities with the class during its BEAMS week. The mentor visits extend and reinforce the BEAMS week and help integrate it into the school year.

Monday	Tuesday:	Wednesday	Thursday	Friday
CEBAF Orientation: • Site Tour • The very cold world of liquid nitrogen	Problem Solving: Nuclear Physics Simulation Math: Graphing, pt. 1 - Battleship	Observation: Oobleck - A mystery substance Math: Graphing, pt. 2 - Applications	Observation: Telescope Activity Problem Solving: Mystery Math 7-9:00 pm Parent's Open House	Measurement: Slow Bicycle Race Observation: Microscope Activities

Typical weekly BEAMS Schedule. Classes are on site daily from 8:30 a.m. until 1:30 p.m.

Figure 2

BEAMS Extension. While the short-term motivational benefits of BEAMS are evident in anecdotes and attitudes, several education experts have advised us that the likelihood is small of a long-term impact that would influence high school course selection, achievement, and career and college aspirations. After all, how much effect can one week of school at age 10 to 12 have? These experts have suggested that a key success factor would be to provide age/grade-appropriate motivational activities year after year. CEBAF is working with school partners to extend BEAMS into a multi-year program providing motivational science and math experiences spanning several school years.

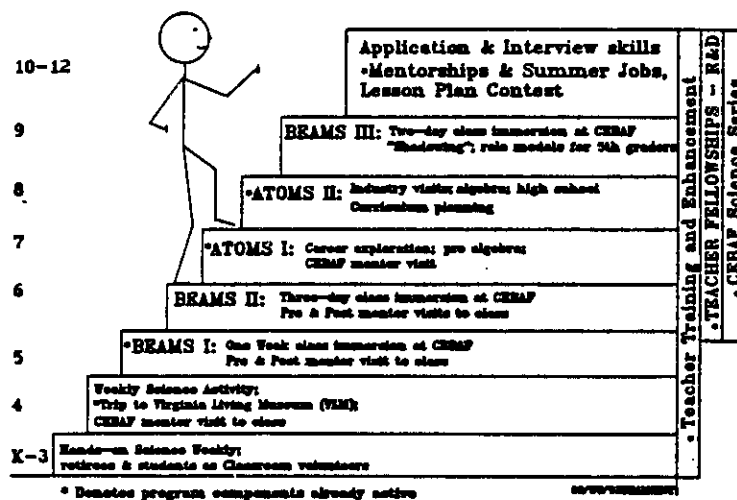
² CEBAF, BEAMS Student Handbook, 1991 and 1992 Editions.

The primary goals of the expanded BEAMS initiative are:

- To motivate students about math, science, and school so they enroll and succeed in challenging courses and pursue education until they are well prepared for workforce entry and lifelong learning in a globally competitive economy;
- To enhance the preparation and prestige of math and science teachers so they have high expectations for all students and teach in a way that models the process and excitement of the subject; and
- To evaluate the program's impact via annual monitoring of attitudinal, course-selection, and achievement measures of participating and control populations.

To accomplish these goals, the planned focus is on grades 4 through 10, with preparation in grades K-3 and follow-up in grades 11 and 12. The program would involve teachers, school administrators, guidance counselors, parents, students, and other business partners. It incorporates other successful school-business partnership programs operating in the community. The program would bring 5th, 6th, and 9th grade classes with their teachers to CEBAF for 2 to 5 days of immersion and activities. Fourth graders would participate in outreach and science field trips. Seventh and 8th grades would be visited by a CEBAF "mentor" and participate in a career awareness program involving other business partners. For 10th grade the focus would be on careers and college, emphasizing preparation needed, and application and interviewing skills. Built into the 9th-12th grade activities would be opportunities for the students to work with and motivate children in the earlier grades. We propose to re-direct our existing successful teacher enhancement and orientation programs to serve the teachers, administrators, and counselors working on a day-to-day basis with the participating students to ensure the coherence and integration of the students' overall educational experience with the goals and objectives of the program.

Specific objectives have been identified in a preliminary manner for students, teachers, parents, school administrators, and CEBAF staff volunteers. Discussions are underway with school district partners to plan the transition from the current BEAMS program, and to ensure year-after-year participation of the same students.



Plan for the Expanded BEAMS Program

Figure 3

BEAMS Evaluation. One goal of BEAMS is to motivate the students and teachers about math and science. A broader goal is to determine whether this type of in-depth experience and integration of the classroom with a real workplace has a significant impact. Does it influence the student's interest in science and math academically or for a career? Does it affect a student's overall motivation for and performance in school?

To answer these questions, a multi-year evaluation effort involving BEAMS students and control students has been initiated. To measure the outcomes of interest, we monitor the attitudes, performance, and choices of participating students from their BEAMS experience through middle school, high school, and beyond, to the start of their careers. Our evaluation program relies on the school district partner to identify control students who did not participate in BEAMS, and to provide us with yearly data on participants and controls. The types of data required are readily available to the school district and include: standardized test scores, math and science course choices through middle and high school, grade point average, and graduation status. We are in the process of establishing data bases and working out the details of the long-range evaluation program.

Initial feedback includes student, teacher, and parent questionnaires and the results of an attitudinal survey administered to the students and to control classes two weeks before and four weeks after their BEAMS week. For the 1992/1993 program, an attitudinal survey administered near the end of the school year was added for the classes that attended BEAMS in the fall. The 1991 and 1991/1992 surveys³ indicated that the control group's attitude toward math, science, and school became significantly negative between the pre- and post-surveys. Compared with the controls, BEAMS has significant favorable effects.

- Student interest in careers in math and science and intention to take courses increases
- Students' reports that they personally know a scientist or engineer increase
- Students' (especially blacks and females) perceived difficulty of science and/or math decreases
- More girls realized women can be scientists
- Students gained a richer, more specific, and more realistic idea of what scientists do

One negative finding was that students' sense of their parents' support for math/science achievement decreases. We attribute this to the students' disappointment when their parents failed to show sufficient interest to attend the evening parents open house.

Qualitative written student feedback indicated that they were eager to spend more time in the program each day and that they wished the experience would continue beyond the week. They particularly valued the respect and individual attention they received from CEBAF staff.

From the teacher surveys, we learned that 80% of the teachers were initially apprehensive about the program due to the difference from a traditional school setting, concern about the academic preparation of their students, and concern about discipline problems. Of those initially apprehensive, 77% reported, much to their relief, that the students' academic level and preparation was fine and that discipline problems were minimal due to constant activity and high student interest. All of the teachers believed the activities and content were appropriate for the students, with 98% judging the age group to be appropriate. The teachers also remarked that the program was an excellent horizon-expanding experience that the students will remember for a long time.

Feedback from parents was obtained in person at a participatory and informative "Open House" held one night each BEAMS week and by using an evaluation form sent home from school. Parent participation was disappointing (but we are told much better than the

³ C. Birmingham, et al, "Analysis of BEAMS Survey Results, 1991-92," CEBAF publication (1992).

school district expected), with approximately one-third of families represented at the "Open House." All parents responding to the survey would recommend BEAMS to other parents, and 71% reported that during the BEAMS week their child spoke about school activities significantly more than usual.

BEAMS Replication. Although definitive results demonstrating the overall effectiveness of BEAMS are not yet available, early feedback suggests the program has significant benefits. Therefore, we offer the following guidance for organizations interested in launching a BEAMS-type program. The first requirement is to have an interested and committed partner school district and a business or laboratory. Identify each other's strengths, limitations, and any major safety, liability, and logistical issues. To develop and implement the program:

- Identify and agree on each partner's responsibilities and program logistics.
- Develop or find and adopt enough grade-appropriate hands-on activities to interest, inspire, and challenge the students for five school days. At CEBAF we focus less on learning facts and "content" and more on exercising science and math "process" skills, such as questioning, observation, data-taking, and prediction. It is important to have activities relevant to the main science/math field(s) of the business or laboratory.
- Recruit enthusiastic staff volunteers to conduct the activities and work as role models with the students. Have the role models test the activities before using them. Encourage role models to share their interests and school experiences with the students to establish rapport.
- With teacher input, create a generic schedule for the week.
- Plan and hold a teacher orientation. The teacher participants are justifiably nervous about the content and quality of the experience and about student preparation and behavior. They also need to become sufficiently familiar with the activities and the site to serve as leaders and guides for their students.
- Start slowly: only one class at a time, with a few weeks to recover and modify the schedule or activities before the next class arrives. Build up gradually to maximum capacity.
- Have fun.

The CEBAF Science Series program

The CEBAF Science Series offers monthly interactive evening seminars on diverse scientific topics. The primary audience is 6th through 12th grade students, who attend on a voluntary basis, with teachers, parents, and the public also invited. Topics are selected to complement the middle/high school curriculum and include sufficient "gee whiz" to fascinate the younger students and sufficient content to educate the older ones. Examples include subjects ranging from physics and lasers, to dermatology, marine biology, geology, and environmental science. We encourage the presenters to build audience participation into their programs.

Due to unpredictable attendance, we have entered into a partnership with Newport News Public Schools Cable TV station to videotape each program for closed circuit viewing by overflow crowds, for later broadcast to the community, and for loan to interested teachers from any school district. Videotapes of more than 25 programs are available from CEBAF, and an updated listing⁴ is made available to teachers.

Other student outreach partnership programs

CEBAF participates in numerous partnerships, many targeting students traditionally underrepresented in science and mathematics. These partnerships help ensure integration of a short CEBAF experience into a longer-term effort managed by the partners, which are local

⁴ "CEBAF Science Series Video Presentations Available on Videotape," (updated monthly).

school districts, universities/colleges, and industries. Examples include:

- CHROME (Cooperative Hampton Roads Organizations for Minorities in Engineering) is an organization composed of business, government, and school district partners, which sponsors a network of school-centered science- and engineering-oriented clubs for minority students and girls in middle and high schools throughout Hampton Roads. CEBAF is a board member of CHROME, hosts site visits for CHROME clubs, sends speakers to CHROME clubs, and uses CHROME to recruit students and teachers for educational programs.
- ATOMS (Adventures in Technology = Options in Math and Science) is a career exploration program for average middle-school students, many of them African Americans and females. The goal of this cooperative program between five local school districts, three high-tech businesses, Thomas Nelson Community College, NASA-Langley, and CEBAF, is to introduce students to the many careers (primarily at the technician level) available in scientific and technical fields. Six of CEBAF's ten ATOMS volunteers are minority engineers, technicians, and computer scientists.
- The Regional Summer Institute is a four-week summer school program for "at-risk" eighth grade students from five local school districts. CEBAF has entered into a partnership with Thomas Nelson Community College, the participating school districts, and NASA-Langley to offer a variety of experiences to heighten student self-esteem, study skills, and interest in science and technical careers.
- The Achievable Dream Program is a summer and school year enrichment and self-esteem building program for inner-city, at-risk students from Newport News. Students are recruited in fourth grade and can participate through middle school.
- Various programs funded by the National Science Foundation through a university bring minority students and/or girls to CEBAF for special activities.
- A two-week summer residential program for students and teachers from Appalachia involves the participants in research projects, cultural, and educational activities.

Summary

The BEAMS program, CEBAF-SITE, and CEBAF's other educational programs for students and teachers show promise for benefiting pre-college science and math education. As our programs have developed and more people have become aware of them, the demand has increased. With CEBAF's talented and enthusiastic scientific and technical staff and the rich scientific environment, we can provide motivational and informative learning opportunities for students and teachers. By developing and evaluating innovative educational partnerships, we test models for how laboratories and businesses can help strengthen pre-college math and science in the U.S.

Biosketch

Dr. Beverly Hartline joined the Continuous Electron Beam Accelerator Facility (CEBAF) in 1985, and in 1989 she became Associate Director and Project Manager. In 1990 she assumed responsibility for CEBAF's precollege education programs. Previously she worked at Lawrence Berkeley Laboratory, NASA-Goddard Space Flight Center, Science, and taught college. She received her Ph.D. in geophysics (University of Washington), and her B.A. in chemistry and physics (Reed College, in Portland, Oregon). Kathryn Strozak is CEBAF's Education Program Coordinator.